10/562301

METHOD OF ENCODING A LATENT IMAGE

The present application claims priority of Australian
provisional patent applications 2003903501 and 2003905861,
5   the disclosures of which are incorporated herein by
reference.

Field of the Invention

10   The present invention relates to a method of encoding a
latent image. Embodiments of the invention have
application in the provision of security devices which can
be used to verify the legitimacy of a document or
instrument, for example, a polymer banknote.

15

Background to the Invention

In order to prevent unauthorised duplication or alteration
of documents such as banknotes, security devices are often
20   incorporated within banknotes as a deterrent to copyists.
The security devices are either designed to deter copying
or to make copying apparent once copying occurs. Despite
the wide variety of techniques which are available, there
is always a need for further techniques which can be
25   applied to provide a security device.

Summary of the Invention

The invention provides a method of encoding a latent
30   image, the method comprising:
        a)   providing a latent image to be encoded, the
latent image having a plurality of latent image elements,
each latent image element having a visual characteristic
which takes one of a predetermined set of values;
35   b)   providing a secondary pattern having a
plurality of secondary image elements, the secondary
pattern being capable of decoding said latent image once

the latent image has been encoded;

        c)   relating the latent image elements to the
secondary image elements; and

        d)   forming a primary pattern comprising a
5   plurality of primary image elements which correspond to
said secondary image elements displaced in accordance
with the value of the visual characteristic of the latent
image elements to which said secondary image elements are
related.

10

The image elements are typically pixels (i.e. the smallest
available picture element), however, the image elements
may be larger than pixels in some embodiments - e.g. each
image element might consist of 4 pixels.

15

The visual characteristic typically relates to the density
of the image elements. That is, where the latent image is
a gray-scale image, the visual characteristic may be a
gray-scale value and where the latent image is a colour
20   image, the visual characteristic may be a saturation value
of the hue of the image element.

The number of values in the predetermined set of values of
the visual characteristic is typically dependent on the
25   configuration of the secondary pattern. The secondary
pattern typically consists of rectangular groups of image
elements arranged in such a way that if the secondary
pattern were superimposed upon itself at a certain
displacement it would eclipse it's own image. The number
30   of image elements in each group of image elements limits
the number of values in the predetermined set of values.

For example, a typical secondary pattern for use in
encoding a gray-scale latent image is a rectangular array
35   consisting of a plurality of pure opaque vertical lines,
each line being N pixels wide and separated by pure
transparent lines of the same size. Such a secondary

pattern can be used to encode a latent image having up to
N + 1 different gray-scale values.

In one embodiment the number of visual characteristics (S)
5   is determined in accordance with the equation:

$$S = (WR/25.4X) + 1, \text{ where:}$$

W is the to be printed width of the primary pattern;
R is the printer resolution in image dots per square inch;
and
10 X is the width of the primary pattern in pixels.

In some embodiments, relating the latent image elements to
the secondary image elements involves associating the
latent image elements with secondary image elements,
15 whereafter the secondary image elements are displaced in
dependence on the value of the visual characteristic of
the latent image elements with which they are associated.

In other embodiments, relating the latent image elements
20 to the secondary image elements comprises separating the
latent image into a plurality of masks corresponding to
each value of the visual characteristic, forming a
plurality of displaced partial secondary patterns, and
using the masks to modify the plurality of displaced
25 partial secondary patterns and combining the modified
displaced partial patterns to form said primary pattern.

Typically, the secondary pattern and the latent image will
be rectangular and hence their image elements will be
30 arranged in a rectangular array. Accordingly, displacing
image elements will usually involve displacing image
elements along an axis of the rectangular array. However,
the image elements may be arranged in other shapes.

35 In one embodiment where image elements are displaced along
the horizontal axis of the array and there are S different
values of the visual characteristic, secondary image

- 4 -

elements associated with latent image elements having a
first value of the visual characteristic are displaced
horizontally by one image element, and each subsequent
visual characteristic is displaced by a further image

5   element so that the Sth shade is displaced by S image
elements.

However, any number of different displacement schemes may
be used. For example, the image elements may be displaced

10 in accordance with the formula: displacement (D) = $(N-1)*$
$[(S-S_{min})/(S_N- S_{min})]$; where S is the value of the visual
characteristic being displaced, S_{min} is the sparsest density
value of the visual characteristic and S_N is the densest
value of the visual characteristic.

15

Typically, the method will involve forming the latent
image from an original image by image processing an
original image to reduce the number of values of the
visual characteristic in the original image to the number

20 of values required in the latent image.

The invention also provides a method of encoding a
plurality of latent images, the method comprising:

        a)   providing a plurality of latent images to

25 be encoded, each latent image having a plurality of latent
image elements, each latent image element having a visual
characteristic which takes one of a predetermined set of
values;

        b)   providing at least one secondary pattern,

30 each at least one secondary pattern having a plurality of
secondary image elements, each secondary pattern being
capable of decoding one or more of said latent images once
the latent images have been encoded;

        c)   relating the latent image elements to the

35 secondary image elements of the secondary pattern which is
to decode the latent image;

        d)   forming a primary pattern for each primary

pattern comprising a plurality of primary image elements
which correspond to said secondary image elements
displaced in accordance with the value of the visual
characteristic of the latent image elements to which said
5   secondary image elements are related; and

          e)   combining said primary patterns at angles
to one another to form a composite primary pattern
encoding each of said latent images.

10   The invention also provides a primary pattern encoding a
latent image, said primary pattern comprising:
          a plurality of primary image elements which can
be decoded by a secondary pattern comprising a plurality
of secondary image elements, said primary image elements
15   being displaced relative to respective ones of said
secondary image elements, the displacement being
determined on the basis of the value of the visual
characteristic of latent image elements related to
respective ones of said secondary image elements.

20

The invention also provides a primary pattern as claimed
in claim 29 wherein said primary pattern is embossed on a
polymer substrate.

25   Further features of the invention will become apparent
from the following description of preferred embodiments of
the invention.

Brief Description of the Drawings

30

The preferred embodiments will be described with reference
to the accompanying drawing in which:

          Figure 1 is an original image of the example of
35   the second preferred embodiment;
          Figure 2 is a latent image of the example of
Figure 1;

Figures 3a, 3b, and 3c are masks which are used
in the example of Figure 1;

Figure 4 shows the different displacements used
for different shades;

5   Figure 5 illustrates displaced partial secondary
patterns corresponding to Figure 4;

Figures 6 through 13 illustrate how the masked
partial secondary patterns may be combined to form the
latent image;

10   Figures 14 and 15 illustrate how the latent image
may be retrieved using a decoding screen which comprises
the secondary pattern;

Figure 16 illustrates left and right phase
shifts;

15   Figure 17 illustrates an eight shade primary
pattern; and

Figure 18 is Figure 17 dithered to reduce the
shades to black and white.

20 Description of the Preferred Embodiments

In each of the preferred embodiments the method is used to
produce a primary pattern in which a latent image is
encoded. The primary pattern in each case is produced by
25 modification of a secondary pattern in accordance with a
relationship which is established between the secondary
pattern and the latent image which is to be encoded. The
secondary pattern is also known as a decoding screen. The
latent image can subsequently be viewed by overlaying the
30 primary pattern with the secondary pattern. If more than
one latent image is encoded, this forms a composite
primary pattern.

Gray-scale embodiments

35

In the first and second preferred embodiments, the method
is used to encode gray-scale images. In these

embodiments, the set of values of the visual
characteristic which is used as the basis of determining
which displacement are to be applied to the secondary
pattern is a set of different shades of gray.

5

In the first and second preferred embodiments the image
elements are pixels. Herein, the term "pixel" is used to
refer to the smallest picture element that can be produced
by the selected reproduction process - e.g. display

10   screen, printer etc.

In these embodiments the secondary pattern consists of
rectangular groups of pixels arranged in such a way that
if the secondary pattern is superimposed on itself with a

15   certain displacement it eclipses it's own image (to the
extent that the secondary pattern and the superimposed
secondary pattern overlap). Each pixel in a group is
either pure opaque (black) or pure transparent (white).
The opaque and transparent groups alternate along at least

20   one co-ordinate with at least approximate regularity.
These groups will be referred to as "super pixels".
Typically, the secondary pattern will be a rectangular
array of pixels. However, the secondary pattern may have
a desired shape - e.g. the secondary pattern may be star-

25   shaped.

A typical secondary pattern for use in encoding a gray-
scale latent image consists of a plurality of pure opaque
vertical lines, each line being N pixels wide and

30   separated by pure transparent lines of the same size.
Such a secondary pattern can be used to encode a latent
image having up to N + 1 different gray-scale values.

In each of these embodiments, the latent image is formed

35   from an original image. In gray-scale embodiments, the
original image is typically a picture consisting of an
array of pixels of differing shades of gray. However, the

- 8 -

original image may be a colour image which is subjected to
image processing to form a gray-scale image before
subsequently being turned into a latent image. The
original image is observed, in a simplified form, as the
5   latent image when the secondary pattern and the primary
pattern are overlaid.

In the gray-scale embodiments the latent image is a
picture consisting of rectangular blocks of pixels. Each
10   block consists of pixels with the same shade of gray. The
number of shades of gray which can be used in different
blocks are those required to display the latent image.
The shades used in the latent image are a reduced set of
the shades in the original image. The shades can be
15   chosen in a number of different ways and might range from
pure white to pure black. The blocks of pixels in the
latent image do not have to be the same size as the super
pixels, however, in many embodiments they will be the same
size.
20

The maximum number of shades (N_s) which can be used in the
latent image is controlled by the resolution of the
reproduction technique and the preferred size of groups of
pixels in the secondary pattern. The number of encoded
25   shades cannot exceed: N_s = (1 + the number of pixels in a
super pixel of the Secondary Pattern)

In the first preferred embodiment, the secondary pattern
is chosen to be a rectangular array (or matrix) of pixels.
30   After a suitable secondary pattern is chosen, the
secondary pattern is mathematically converted to a primary
pattern as follows:

1.   The total number of possible shades (N_s) is
35   determined and selected from the composition of the
secondary pattern (i.e. the maximum number of shades which
the chosen secondary pattern is capable of encoding).

Using standard image processing techniques known to persons skilled in the art, an original image is processed and digitised into an image containing N_S different shades of gray. This image is the latent image.

5

2.   Each pixel in the latent image is assigned a unique address (p,q) according to its position in the [p x q] matrix of pixels. (If the latent image or the secondary pattern is not a rectangular array then the

10   position of pixels can be defined relative to an arbitrary origin, preferably one which gives positive values for both co-ordinates p and q).

3.   Each shade of gray in the latent image is

15   designated S_m, where S_1 is the palest shade of gray and S_{NS} is the darkest shade of gray (m = an integer between 1 and N_S).

4.   Each pixel in the latent image is designated as

20   belonging to one of S_1-S_{NS}.

5.   Each pixel in the secondary pattern is assigned a similarly unique address (p,q) according to its position in the [p x q] matrix.

25

6.   The S_1-S_{NS} designation of each (p,q) pixel in the latent image is now assigned to the corresponding (p,q) pixel in the secondary pattern to thereby relate pixels in the latent image to pixels in the secondary pattern.

30

7.   A mathematical operation is performed on each individual pixel in the secondary pattern to move it along one of the image axes according to the shade of gray (S_m) assigned to it. This movement may be either right or

35   left, or up or down, or combinations of movements along both of the axes simultaneously. A variety of displacements can be employed. In a common embodiment,

- 10 -

each pixel is displaced as follows:

by 1 pixel for S_1

. . . . .

5 by N_S pixels for S_{NS}

or, in general,

by m pixels for S_m

10

Alternatively, a formula such as the following can be
used:

$$D = (N_S-1) \times [(S-S_{min})/(S_{max}-S_{min})]$$

15

where D = the displacement (i.e. the number of pixels to
be moved)

Direct assignment of equally spaced D values to particular
20 shades via a table is also valid method.

The pairing of darkest shade with highest shift can also
be reversed i.e. lightest shade with highest shift will
provide a similar result.

25

The formulae shown above provide a broad contrast range
and hence make the latent image relatively easy to see
when the secondary pattern overlays the primary pattern.
Other formulae will be appropriate in other applications.

30

The resulting image is known as the primary pattern. In
the primary pattern, pixels of the secondary pattern have
been displaced in accordance with the shade of gray of the
pixel of the latent image with which they are related.

35

In the second preferred embodiment, once an appropriate
secondary pattern has been chosen, the secondary pattern

- 11 -

is manually converted (e.g. by a person manually operating
a computer running appropriate software) to the primary
pattern as follows:

5   1.   The total number of possible shades (N_S) is
determined and selected from the composition of the
secondary pattern.

2.   Using standard image processing techniques known
10   to persons skilled in the art, an original image is
processed and digitised into an image containing N_S
different shades of gray. This image is the latent image.

3.   The latent image is then separated into N_S masks
15   where each mask contains only the pixels belonging to one
shade of gray (i.e. belonging to S_1-S_{NS}). This is achieved
using standard methods in commercially available imaging
programs. After the masks have been formed each mask
contains a unique set of pixels from the latent image and
20   every pixel of the latent image can be found in only one
of the masks. If all of the masks are combined correctly,
the original picture can be restored.

4.   A displaced partial secondary pattern is created
25   for each mask, with the displacement of each partial
secondary pattern corresponding to the shade of the pixels
of the latent image to which the mask relates. These
displaced partial secondary patterns are designated S^*_1-
S^*_{NS}. This displacement may be either right or left, or up
30   or down, or combinations of movements along both of the
axes simultaneously. The displacement is defined by a
mathematical operation (algorithm) performed on each
individual pixel S_1-S_{NS}. The displacement is different for
each S_1-S_{NS}. A variety of displacements can be employed.
35   In a common embodiment, each pixel is displaced as
follows:

- 12 -

by 1 pixel for $S*_1$

.....

by N_S pixels for $S*_{NS}$

5   or, in general,

by m pixels for $S*_m$

Alternatively, formulas such as the following can be used:

10

$$D = (N_S-1) \times [(S-S*_{min})/(S*_{NS}-S*_{min})]$$

where D = the displacement (i.e. the number of pixels to
be moved)

15

Direct assignment of equally spaced D values to particular
shades via a table is also valid method.

The pairing of darkest shade with highest shift can also
20 be reversed—i.e. lightest shade with highest shift will
provide a similar result.

The formulae shown above provide a broad contrast range.
Other formulae will be appropriate in other applications.

25

5.   The masks are used to cut-out sections of the
corresponding displaced partial secondary patterns,
thereby relating the pixels of the latent image to the
partial secondary patterns. The resulting N_S masked
30 partial secondary patterns images are each portions of the
displaced secondary pattern.

6.   The masked partial secondary patterns are now
recombined into the primary pattern. The primary pattern
35 is thus, a displaced version of the secondary pattern,
where the displacement of individual pixels in the
secondary pattern is based on a relationship established

- 13 -

between pixels in the latent image and pixels in the
secondary pattern.

Colour Embodiments

5

The methods of the third and fourth preferred embodiments
are suitable for producing colour effects in encoded
colour images. In the third and fourth embodiments,
saturation level is the visual characteristic which is
10   used as the basis for encoding the image. As in the first
and second embodiments the image elements are pixels.

The secondary pattern of the third and fourth embodiments
is best explained with reference to the black and white
15   (B&W) secondary pattern of the first and second
embodiments. A colour secondary pattern can be derived
from a B&W secondary pattern by substituting pixels of the
chosen secondary hues for the black groups of pixels in a
B&W secondary pattern in a regular fashion so that the
20   secondary pattern has a regular pattern of secondary hues.
These regular patterns may involve changing the hue of
each succeeding pixel or multiple of pixels in a regular
and repeating fashion. The saturation levels of these
secondary hues are determined as the maximum saturation
25   levels found in the latent image. The transparent (white)
areas may be filled with black or left white dependant on
the requirements of the colour separation technique.

In these embodiments, secondary hues are colours that can
30   be separated from a colour original image by various means
known to those familiar with the art. A secondary hue in
combination with other secondary hues at particular
saturations (intensities) provides the perception of a
greater range of colours as may be required for the
35   depiction of the subject image. Examples of secondary
hues are red, green and blue in the RGB colour scheme.
Another colour scheme which may be used to provide the

- 14 -

secondary hues is CYMK.

In these embodiments, saturation is the level of intensity
of a particular secondary hue within individual pixels of
5   the original image. Colourless is the lowest saturation
available; the highest corresponds to the maximum
intensity at which the secondary hue can be reproduced.
saturation can be expressed as a fraction (i.e. colourless
= 0 and maximum hue =1) or a percentage (i.e. colourless
10   = 0% and maximum hue =100%) or by any other standard
values used by practitioners of the art.

As in the first and second embodiments, the latent image
will typically be provided by forming it from an original
15   image. Typically, the original image will be a picture
consisting of an array of pixels of secondary hues with
differing saturations of each secondary hue. The original
image is observed, in a simplified form, as the latent
image when the secondary pattern and the primary pattern
20   are overlaid. The latent image is a digitised and
pixilated version of the original image.

The maximum number of saturation levels (N_s) of a
particular secondary hue which can be visible in the
25   Latent Image is controlled by the resolution of the
reproduction technique and the preferred size of groups of
pixels in the secondary pattern. The number of encoded
saturation levels cannot exceed: N_S = (1 + the number of
pixels in a super pixel of the secondary pattern)

30
The methods of the third and fourth embodiments are also
controlled by the number of secondary hues (N_H) used in the
colour separation technique.

35   In the third embodiment, once a suitable secondary pattern
has been chosen, the following steps are undertaken in the
mathematical conversion of the Secondary Pattern to the

- 15 -

Primary Pattern:

1.   The total number of possible saturation levels
(N_S) is determined and selected from the composition of the
5   secondary pattern.

2.   Using standard image processing algorithms known
to persons skilled in the art, an original image is
processed and digitised to the latent image, which is made
10   to contain a maximum of N_S saturation levels in each one of
the hues.

3.   Each pixel in the latent image is analysed
sequentially to determine the saturation of the secondary
15   hue in the pixel.

4.   Each pixel in the latent image is allocated a
unique address [(p,q)nh] according to its position in the
[p x q] matrix and its hue, nh (nh = 1 for hue number 1,
20   nh = 2 for hue number 2, ... nh = N_H for hue number N_H).
Again, as in the first preferred embodiment the co-
ordinates may be defined relative to a reference point
rather than as positions in a matrix, especially where the
latent image is not a rectangular array of pixels.

25

5.   Each saturation level in the latent image is
designated S_m, where S_1 is the lowest saturation and S_{NS} is
the most intense saturation (m = an integer between 1 and
N_S). The secondary hue in each pixel of the latent image
30   is designated as belonging to one of S_1-S_{NS}, and the pixel
is addressed accordingly, [(p,q)nh,S_m].

6.   Each pixel in the secondary pattern has a
similarly unique address [(p,q)nh,ns] according to its
35   position in the [p x q] matrix, its hue, and its
saturation. The secondary pattern is now divided into X
blocks of pixels (X = an integral number), each of which

represents the smallest possible repeating unit in the
secondary pattern. The addresses of the pixels in each
block are modified to indicate their block number, x, as
follows $[(p,q)nh,NS,x]$ (x = an integral number between 1
5   and X)

7.   Pixels $[(p,q)nh,S_m]$ in the latent image are now
assigned a block number, x, equal to the block number of
the pixel having the same values of p and q in the
10 secondary pattern, without regard for the respective
values of nh and S_m. Pixels in the latent image now have
an address $[(p,q)nh,S_m,x]$ in which the value of x
corresponds to that of the pixel having the same values of
p and q in the secondary pattern. Thus, pixels of the
15 latent image have been related to pixels of the secondary
pattern.

8.   Using the latent image, the average saturation
S_m^{av} is now calculated for each hue nh for all of the pixels
20 in each block, x. Each block is consequently assigned a
descriptor $\{S_m^1, S_m^2, ...S_m^{nh}\}x$ to describe the average
saturation, S_m, for each hue nh in each block x. The
average saturation can only take one of the available
saturation levels. S_m is the value of saturation which is
25 subsequently used to determine how pixels in the secondary
pattern are displaced.

9.   In each corresponding block x in the Secondary
Pattern, pixels of each hue nh are now displaced along one
30 of the image axes according to the saturation level of the
hue (S_m) in the descriptor for that block, $\{S_m^1, S_m^2,$
$...S_m^{nh}\}x$. This movement may be either along one axis or
another, or combinations of movements along both of the
axes simultaneously. As in the previous embodiments, a
35 variety of displacements can be employed. In a common
embodiment, each pixel is displaced as follows:

- 17 -

by 1 pixel for S_1

.....

by N_S pixels for S_{NS}

5   or, in general,

by m pixels for S_m

Alternatively, a formula such as the following can be
10   used:

$$D = (N_S-1) \times [(S-S_{min})/(S_{max}-S_{min})]$$

where D = the displacement (i.e. the number of pixels to
15   be moved)

Direct assignment of equally spaced D values to particular
saturation levels via a table is also a valid method.

20   The pairing of the most intense saturation with highest
shift can also be reversed i.e. lightest saturation with
highest shift will provide a similar result.

The formulae shown above provide a broad contrast range.
25   Other formulae will be appropriate in other applications.

The resulting image is the primary pattern and is, in
effect, a displaced version of the secondary pattern,
where the displacement is dependent on the relationship
30   established between pixels of the latent image and pixels
of the secondary pattern.

In the fourth embodiment, a suitable secondary pattern is
chosen and then the following steps are undertaken in the
35   manual conversion of the secondary pattern to the primary
pattern:

1.   The total number of possible saturation levels
(N$_S$) is determined and selected from the composition of the
secondary pattern.

5   2.   Using standard image processing techniques, an
original image is processed and digitised in order to
provide the latent image.

3.   The latent image is then colour separated into a
10   number of hue images representing each of the secondary
hues, using standard image processing techniques. Each
hue image is a gray-scale picture produced as a colour
separation from the original image, wherein the shade of
gray represents a particular saturation of the particular
15   hue.

4.   Each hue image is analysed to determine the
highest saturation level of each secondary hue. These
values are subsequently used to define the secondary hue
20   saturation levels used later to produce displaced partial
secondary patterns as discussed in further detail below.

5.   Using standard image processing techniques, the
dynamic range of each hue image is expanded to the maximum
25   available (the limit may vary depending on the software
being used), the dynamic range is then reduced to N$_S$
saturation levels, before the dynamic range is expanded
again.

30   6.   Each hue image is now separated into N$_S$ masks,
each containing only the pixels belonging to one hue (i.e.
belonging to $S*_1$-$S*_{NS}$) using standard methods in
commercially available imaging programs such as Photoshop
(available from Adobe Systems Incorporated,
35   www.adobe.com). Each mask contains a unique set of pixels
from the image and every pixel can be found in only one of
the masks. If all of the masks from one secondary hue set

are combined at their correct saturation levels, the
original hue image is restored.

7. N_H partial secondary patterns are created by
5   colour separation of the secondary pattern, each of these
partial secondary patterns only contains a single
secondary hue.

8.   A displaced partial secondary pattern is created
10 for each mask corresponding to it's hue and saturation.
The saturation levels are designated $S*_1$-$S*_{NS}$. The
displacement may be either right or left, or up or down,
or combinations of movements along both of the axes
simultaneously. The displacement is defined by a
15 mathematical operation (algorithm) performed on each
individual pixel $S*_1$-$S*_{NS}$. The displacement is different
for each $S*_1$-$S*_{NS}$. A variety of displacements can be
employed. In a common embodiment, each pixel is displaced
as follows:

20

by 1 pixel for $S*_1$

.....

by N_S pixels for $S*_{NS}$

25 or, in general,

by m pixels for $S*_m$

Alternatively, a formulas such as the following can be
30 used:

$$D = (N_S-1) \times [(S-S*_{min})/(S*_{NS}-S*_{min})]$$

where D = the displacement (i.e. the number of
35 pixels to be moved)

Direct assignment of equally spaced D values to particular

saturation levels via a table is also valid method.

The pairing of most intense saturation with highest shift can also be reversed i.e. lightest saturation with highest

5   shift will provide a similar result.

The formulae shown above provide a broad contrast range. Other formulae will be appropriate in other applications.

10   9.   The masks are used to cut-out sections of the corresponding displaced partial secondary patterns, thereby relating pixels of the latent image to pixels of the partial secondary patterns. The resulting N_S x N_H displaced partial secondary patterns are each assemblies

15   of portions of the corresponding, shifted secondary pattern.

10.   The displaced partial secondary patterns are now recombined to form the primary pattern which is a

20   displaced version of the secondary pattern where the displacement is based on the saturation levels of the latent image pixels with which a relationship has been established.

25   <u>Alternative embodiments</u>

A number of variations may be made to the foregoing embodiments of the invention, for example, while the image elements are typically pixels the image elements may be

30   larger than pixels in some embodiments - e.g. each image element might consist of 4 pixels in a 2 x 2 array.

In some embodiments, once the primary pattern has been formed, a portion (or portions) of the primary pattern may

35   be exchanged with a corresponding portion (or portions) of the secondary pattern to make the latent image more difficult to discern.

- 21 -

Further security enhancements may include using colour inks which are only available to the producers of genuine bank notes, the use of fluorescent inks or embedding the
5   images within patterned grids or shapes.

The method of at least the first and second preferred embodiments may be used to encode two or more latent images within one primary pattern. For example, with one
10 primary pattern providing the secondary pattern for the other primary pattern and vice versa. This is achieved by forming two primary patterns using the method described above. The primary patterns are then combined at an angle which may be 90 degrees (which provides the greatest
15 contrast) or some smaller angle. The primary patterns are combined into a composite primary pattern by overlaying them at the desired angle and then keeping either the darkest of the overlapping pixels or the lightest of the overlapping pixels, depending on the desired level of
20 contrast.

It is possible, to combine 3, 4, 5 or more latent images into a single composite primary pattern using digital techniques. When combining multiple latent images, there
25 are a number of techniques which may be employed to improve the quality and/or security of the composite primary pattern. The techniques employed will depend on the nature of the latent images, the number of images, and whether the same or different secondary patterns are to be
30 used to decode the primary pattern.

Intersections of the primary patterns in a composite primary pattern can be handled in a number of ways: for example logic operations such as AND, OR or XOR, or
35 subtraction and addition to precise thresholds can be performed. Moreover these techniques can be individually applied to just the intersections or even to intersections

- 22 -

from particular primary patterns in the composite primary
pattern.   This allows image discernment to be optimised
for particular latent images and applications.

5   The goal of such processes is to combine the pixels at the
      intersection in order to provide the greatest contrast in
      competition with the greatest concealment.   The ability to
      make such modifications is a significant advantage of the
      digital techniques of embodiments of the invention.
10

When combining two or more primary patterns, it is
possible to use secondary patterns (hereunder referred to
as "screens") of different width or frequency.   For
example, a first screen which is four pixels wide and a
15   second screen which is five pixels wide so that two
      different secondary patterns are needed in order to decode
      the two different primary patterns encoded within a single
      composite primary pattern.   This has a benefit of added
      security—i.e. if the first screen is compromised, the
20   image encoded by the second screen may still be secure.
      Further, using different screens increases contrast
      between the different primary patterns in the composite
      primary pattern so that they be more readily decoded from
      one another.   This principle may be extended to cases
25   where three or more images are encoded within the same
      composite primary pattern.

When two or more primary patterns are combined at angles
other than 90 degrees the primary patterns themselves will
30   interact, at the very least this interaction will manifest
      itself as a Moiré pattern.   In more extreme cases partial
      decoding of the images can occur, when this occurs in a
      single device it is referred to as self-decoding.

35   For example, when three primary patterns are combined into
      a single primary pattern, not all the primary patterns can
      be combined at 90 degrees.   Another problem is that the

intersections of the first two primary patterns create a
fixed screen such that the third primary pattern will have
a phase position with respect to these intersections. To
get around this problem the angles should be chosen to

5   avoid Moirés and self decoding.

A contributing factor to the selection of optimum screen
angles is defined by the width of the lines. If two
screens (secondary patterns) cross at right angles, the

10   obvious third angle for a third screen would be 45 degrees
but this is only true if the lines are the same widths.
Consider that if the screen lines are of different widths
(so that separate screens are needed to reveal each image
and not just a trivial rotation), then the right angle

15   intersection is a rectangle not a square and the diagonal
of the rectangle will be some other angle other than 45
degrees. Good contrast is achieved when the angle of the
third image is the same is the angle of the longest
diagonal of the parallelograms produced at the

20   intersection of the first two sets of lines regardless of
the first angle.

This means the third primary pattern mostly inhabits the
"white space" left by the first two images. However, this

25   may result in self-decoding. To avoid self-decoding the
angles may be varied by 5 to 10 degrees–i.e. to reduce the
amount of self-decoding while maintaining relatively high
contrast.

30   Other techniques may be used to combine primary patterns.
Using a triple composite primary pattern as an example,
there is only a range of 256 shades with the conventional
8 bit grey scale image. If each primary pattern has the
value as 0 and 255 (black and white) then when these

35   values can be summed by simple addition, the range of
shades would be from 0 to 765 with three images. This is
not processable by standard image processing software

- 24 -

packages. However, by compressing the range of values of
the primary patterns to 0 to 85 then the summed triple
primary pattern would consist of the four shades 0, 85,
170, 255. An exemplary combined triple primary pattern of
5   this type is shown in Figure 17.

If such a device were to be offset printed, this would
require 4 inks and 4 printing plates, and registration of
the four plates would have to be perfect, so this is very
10   difficult to print.

However, the image can be reduced to black and white using
a standard Floyd-Steinburg dither giving the printable
black and white primary pattern shown in Figure 18.

15

Persons skilled in the art would also appreciate that a
dithering program could be coded to process 0 to 765
values to produce black and white image elements.

20   A primary pattern gives the highest security against
counterfeiting when it pushes the limits of the current
printing technology; that is, it utilises the highest
resolution possible.

25   If the number of shades encoded (S) is chosen to be:

$$S = (WR / (25.4 X)) + 1$$

Where: S = the number of shades;
30   W is the intended width of the printed primary
pattern;
            R is the printer resolution in DPI; and
            X is the digital primary pattern width in pixels.

35   A counterfeiter must match or exceed the resolution in
order to copy the primary pattern.

- 25 -

Persons skilled in the art will appreciate that primary
pattern can be positives or negatives—i.e. black and white
lines look the same as white and black. However, when two
or more are combined, a negative may provide better
5   contrast. Consider the positive and negative of two
primary patterns added at right angles:

A dual 90 degree primary pattern will be 75% black and 25%
white and the negative will be 75% white and 25% black.
10

As more primary patterns are added the combination will
become increasingly dark (if you are summing the black
component). As a result the negative will become
increasingly light.
15

Accordingly, depending on the nature of the latent images
it may be advisable to take various combinations of
positive and negative at particular times in the
combination process. For example, after combining the
20   first two primary patterns of a triple primary pattern,
taking the negative before adding the third.

There are several advantages of this process:

25   (a)   It makes the primary pattern more complicated and
harder to copy.
     (b)   It is possible to generate a range of tones that
can help fit the primary pattern into an existing image.
     (c)   It is possible to improve image contrast.
30   In one embodiment, the primary pattern and secondary
pattern are sized so that the elements making up the
primary patterns and secondary pattern are smaller than
the wavelength of visible light and not visible until they
interact.
35

Suitable techniques for producing such primary and
secondary patterns include UV laser lithography and

- 26 -

electron beam technology.

As discussed above, phase movements can be to the right or
left. In the preferred embodiment, the convention of
5   displacements to the right is only a convention; the
element could be moved left with equal effectiveness.
This is illustrated in Figure 16.

Here elements 161,164 are moved to the Left and elements
10   162,163 are moved to the Right but elements 161,162 decode
as the same shade and elements 163,164 decode as the same
shade. The dotted outline 165 shows the position of the
decoding screen when the correct image is displayed.

15   Provided care is taken to avoid collisions between right
and left moving elements these both could be combined
within one encoded image. One way to avoid collisions is
to separate right and left movements in phase to different
horizontal rows of elements. These right and left moving
20   rows do not have to alternate or follow any regular
pattern and could form part of an overall algorithm to
generate a unique screen.

An advantage of using combinations of right and left phase
25   shifts is to reduce the "medallion" or embossed effects
which might otherwise be apparent. This embossed effect
may otherwise permit visualisation of particular primary
patterns without decoding. So the use of right and left
movement significantly improves concealment.
30
While the above discussion of left and right phase shifts
is constrained to a device utilising a decoding screen
composed of vertical lines, the same considerations apply
to horizontal lines or any angle. If the elements were
35   composed of dots they could be moved in any and every
direction only to the extent that movement is required to
impart the correct shade. Similarly, the shifts could be

up and down.

The primary patterns need not necessarily be printed. In
one embodiment, an embossed microstructure may be produced
5   using a combination of electron beam and photolithography.
For example for use as part of polymer banknotes.
Typically, The primary pattern will consist of an embossed
set of 30 micron X 30 micron pixels, wherein each pixel
consists of several sub-pixel areas (e.g. 3 or 4) and the
10 position (i.e. displacement) of the sub-pixel areas within
each pixel in the primary pattern is the means by which
image information is encoded. The sub-pixel block areas
on the embossing dye will be of height 20-30 microns and
because of this relatively large height, will be able to
15 be directly embossed into a polymer substrate. In this
embodiment, the secondary pattern is also an embossed
microstructure and the readout of the latent image
information takes place via the refractive moiré
interference between the two embossed areas.
20

Application of the preferred embodiments

The method of preferred embodiments of the present
invention can be used to produce security devices to
25 thereby increase security in anti-counterfeiting
capabilities of items such as tickets, passports,
licences, currency, and postal media. Other useful
applications may include credit cards, photo
identification cards, tickets, negotiable instruments,
30 bank cheques, traveller's cheques, labels for clothing,
drugs, alcohol, video tapes or the like, birth
certificates, vehicle registration cards, land deed titles
and visas.

35 Typically, the security device will be provided by
embedding the primary pattern within one of the foregoing
documents or instruments and separately providing a

- 28 -

decoding screen in the form which includes the secondary
pattern. However, the secondary pattern could be carried
by one end of a bank note while the primary pattern is
carried by the other end to allow for verification that
5 the note is not counterfeit.

Persons skilled in the art will appreciate that the above
embodiments describe a digital latent image technique
based on selective displacements of elements of a decoding
10 screen. The various embodiments allow a great deal of
flexibility in encoding the latent image, e.g. the primary
patterns or composite primary patterns can be modified, or
produced, so as to improve concealment or latent image
contrast. For example, digital techniques allow
15 displacements in irregular directions (e.g. left in one
case and right in the next). This allows for better
concealment of the latent image. Similarly, the pairing
of darkest shade with highest shift can be reversed (i.e.
lightest shade with highest shift will provide a similar
20 result) or made irregular where this is desirable. Indeed,
the displacement algorithm can be one of a wide range of
possible formulae. The formulae can, for example, be used
to optimise the contrast range and hence make the latent
image more easily seen when the secondary pattern overlays
25 the primary pattern. Other formulae will be appropriate
in other applications.

Example

30 In this example, a primary pattern is formed using the
method of the second preferred embodiment.

Figure 1 is an example of an original image. The original
image was of fairly low resolution (104 by 147 pixels) and
35 was a 256-colour image although it is shown in black and
white for the sake of convenience.

- 29 -

The colour image of Figure 1 was then reduced to a
gray-scale picture and the shades of gray were then
equalised to provide the greatest shade separation. The
image was then reduced to four shades of gray using the
5   optimised median cut method with aero diffusion. The
result is illustrated in Figure 2.

In terms of the 8 bit RGB colour scale the shades in this
picture consisted of [228R/228G/228B], [164/R.164G.164/B],
10   [98/R/98G/98B] and [28R/28G/28B]. Further equalisation
was thought to be unnecessary as the full shade range from
phase modulation would only be from 50 to 100% black with
losses due to the use of transparent media.

15   This image was separated into masks representing the
required shades. (Note that the lightest shade
[228R/228G/228B] will serve as a background and therefore
does not need a mask).

20   Figure 3a is the mask for shade 28. Figure 3b is the mask
for shade 98. Figure 3c is the mask for shade 164. These
masks are positive masks as the black areas define the
areas that will be filled with each shade.

25   A secondary pattern of black lines, three-printer pixels
wide, and spaced apart by three-printer pixels is to be
used. Considering the secondary pattern as a reference,
the different shades are to be encoded using a phase shift
of zero printer pixels for the lightest shade, one printer
30   pixel for the 164 shade, 2 printer pixels for the 98 shade
and 3 printer pixels for the 28 shade. This, of course,
will not produce an exact match to the original shades but
this will only affect the contrast and brightness of the
final observed image.

35

The phase shifts are illustrated diagrammatically in
Figure 4, where Figure 4a relates to shade 28, Figure 4b

relates to shade 98, Figure 4c relates to shade 164, and
Figure 4d relates to shade 28. In each case the upper
line relates to the secondary pattern and the lower line
relates to the displaced secondary pattern (primary
5   pattern).

A set of four displaced secondary patterns were prepared
with the required phase difference as illustrated in
Figure 4. These are illustrated in Figures 5a to 5d.
10   Where Figure 5a relates to shade 28, Figure 5b relates to
shade 98, Figure 5c relates to 164 and Figure 5d relates
to shade 228. These partial secondary patterns are 18
times the linear size of the original portrait masks.
That is, 1872 by 2646. The three masks were also expanded
15   from 104 by 147 pixels to 1872 times 2646 pixels. This
expansion was to ensure that sufficient pixels were
available to define the shades in the final image. In
essence, each pixel in the original latent image was
expanded to a super-pixel of 18 by 18 pixels. Therefore
20   it could be defined in shade by a pattern made up of lines
composed of normal pixels.

In order to combine the partial secondary patterns, the
shade 228 image was used as the background and sections of
25   it were replaced by the other shade images as follows:

Firstly the mask of the 164 shade was used to white out
the required areas on the shade 228 image as illustrated
in Figure 6. Figure 7 shows a detail of Figure 6
30   corresponding to the boxed area.

Next the mask for the 164 shade is used to mask out the
164 shade line image as shown in Figure 8. Again a detail
of the right eye (as indicated by the box in Figure 8) is
35   shown in Figure 9. The image shown in Figure 8 was added
to the image of Figure 6 to produce the image shown in
Figure 10. Again a close up of the right eye of Figure 10

is shown in Figure 11.

The process is repeated using the image produced in Figure 10 for the addition of the shade 98 elements using the
5   same procedure as used for shade 164.

This is then repeated with shade 98 to produce the complete latent image shown in Figure 12. Again detail of Figure 12 is shown in Figure 13.
10

Figures 14 and 15 illustrate how, when the secondary pattern is overlaid on the image of Figures 12 and 13, the latent image reappears in a manner which approximates the original latent image.
15

Terminology in provisional application

In the specification of Australian provisional application 2003905861 from which this application claims priority,
20   the term "primary pattern" was used to refer to the decoding screen and the term "secondary pattern" was used to refer to the encoded image. The reader will appreciate that these terms have been reversed in the present specification without altering the intended meaning. The
25   terms have been reversed for consistency with other co-pending applications which reference the present application and its priority application.